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Overview of 1998 Hydrographic Sampling Effort and Near Surface Water Temperature and Salinity Conditions During the Canadian Research Vessel Groundfish Summer Surveys Conducted on the Scotian Shelf and in the Bay of Fundy (4VWX)

by

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ABSTRACT

Hydrographic sampling effort and near surface water temperatures and salinities from the 1970-98 Canadian research vessel summer groundfish, stratified random, bottom-trawl surveys are summarised. The surveys cover NAFO divisions 4VWX. In 1998, sampling dates were typical of those seen in the past. The temperatures and salinities sampled in 1998 at 1 to 5 meters were found to be above average off central Nova Scotia and near average on the eastern Scotian shelf and below average on the western Scotian shelf.

RÉSUMÉ

Les travaux d'échantillonnage hydrographique et les mesures de la température et de la salinité des eaux à proximité de la surface réalisés à partir de navires de recherche canadiens au cours des relevés aléatoires stratifiés d'été du poisson de fond, par chalutage de fond, sont résumés pour la période de 1970 à 1998. Ces relevés couvrent les divisions 4VWX de l'OPANO. Les dates des prélèvements de 1998 étaient semblables à celles des années antérieures. Les températures et salinités mesurées en 1998 de 1 à 5 mètres se sont avérées supérieures à la moyenne au large de la côte centrale de la Nouvelle-Écosse, près de la moyenne dans l'est du plateau néo-écossais et inférieures à la moyenne dans l'ouest de la plate-forme.

INTRODUCTION

The Canadian Department of Fisheries and Oceans conducts bottom-trawl surveys on an annual basis within NAFO unit areas 4VWX as part of its approach for developing scientific advice on the status of groundfish resources. Water temperatures and salinities are measured during these surveys and are summarised on an annual basis (e.g. Page, Losier and McRuer 1994, 1995, 1996, 1997).

The intent of this summary is to briefly describe the extent and nature of the hydrographic sampling effort and conditions of surface water during recent resource assessment surveys, and to place these within a historical context. In so doing, it is hoped that trends and anomalies in conditions and sampling procedures may be identified.

In this overview, we present a summary of sampling effort and the resulting estimates of water temperatures and salinities during the 1970-98 summer surveys conducted within 4VWX. The focus is on the surface water (top 5 meters) conditions in 1998 and how these compare to conditions encountered throughout the history of the survey series. The impact of these conditions on estimates of the status of fisheries resources is not explored.

MATERIALS and METHODS

Data Sources

The hydrographic data summarised in this report were collected during the 1970-98 research vessel, summer groundfish bottom-trawl surveys conducted in NAFO unit area 4VWX. The surveys were conducted by the Canadian Department of Fisheries and Oceans and they cover the Scotian Shelf, eastern Gulf of Maine and the Bay of Fundy (Fig. 1). A standard stratified random design was used each year. The survey domain is divided into 48 strata. The strata boundaries were defined, primarily, on the basis of bottom depth and, secondarily, on the distribution of groundfish, mainly haddock (Doubleday 1981). As in the past, two standard summer surveys were conducted in 1998. Survey N98027 covered the western Scotian Shelf and Bay of Fundy (4X) and N98032 covered the eastern Scotian Shelf (4VW).

From 1970 to 1989, depth profiles of temperature and salinity were taken at about 30% of the sampling stations. Measurements were taken at standard hydrographic sampling depths (0,10,20,30,50,75,100,150, 200, 250 etc. meters). Surface temperatures were recorded with bucket thermometers and sub-surface temperatures with reversing thermometers. Salinities of water samples, taken from the surface bucket or subsurface water bottles, were measured with a laboratory salinometer.

From 1990-97 depth profiles of water temperatures and salinities were measured with a Seabird Model 19 or 25 CTD profiler internally recording conductivity, temperature

and depth using the procedures described below for 1998. CTD profiles were consistently taken at more than 90% of the trawl stations. When a CTD was not available for use, due to malfunction or extreme weather, standard hydrographic profiles (described above) were taken with reversing thermometers attached to water bottles and/or an XBT profile was taken.

In 1998, standard survey hydrographic procedures were used for obtaining vertical profiles of water temperature and salinity at each valid (type 1) bottom trawl sampling station. Type 1 station are stations that were towed for at least 20 minutes with minimal trawl damage. Water temperatures and salinities were measured using an SBE 25. The instrument was attached to a hydrographic wire spooled on a variable speed hydraulic winch. Each CTD profile was taken by lowering the instrument to approximately 10m below the sea surface and allowing it to equilibrate with ambient conditions for about 5 minutes. At some stations a water bottle equipped with a reversing thermometer was triggered at the end of this period to obtain water samples and temperatures for later calibration of the CTD temperature and salinity sensors. After the equilibration period, the instrument was raised to just below the sea surface and then lowered to within a few meters of the bottom at a drop rate of approximately 30-40 $m \cdot min^{-1}$. If calibration samples were not taken at the initial equilibration depth, the instrument was raised approximately 5-10m off the bottom, and a water bottle equipped with a reversing thermometer was triggered at the end of a 5 minute waiting period to obtain water samples and temperatures for later calibration of the CTD. The CTD was then recovered and stored on deck. Sea surface temperatures were also measured at each station with an electronic thermometer. Subsequent to the survey, a laboratory salinometer was used to obtain salinities from the water samples.

Data Analyses

All CTD temperature and salinity profiles have been edited using a combination of quantitative and visual techniques, including range checks, despiking routines and density inversion algorithms. The CTD data have been compared with the reversing thermometer measurements of temperature and the salinometer measurements of water sample salinities for verification of values. Substitutions of outliers and corrections of errors have been applied as necessary.

The edited CTD and bottle data is stored in GSHYD, the hydrographic component of the Maritimes Region Scotian Shelf-Gulf of Maine-Bay of Fundy groundfish ORACLE database. In this report, mean near surface temperatures and salinities were calculated using database values ≥ 1 and ≤ 5 meters. These means were designated as "near surface" conditions. The range was selected to provide allowance for missing values at any of the three depths (1, 3, 5 meters) at which our data are binned, and to include data from surface bucket samples collected before the use of CTD profilers.

RESULTS

Sampling

Mean and 1998

In 1998, sampling was conducted from 6 July (consecutive day 187) to 30 July (consecutive day 211). CTD profiles were obtained from every strata (Fig. 1). As in previous years, the random allocation of the sampling stations resulted in the stations within some strata (e.g. 448, 461, 476, 481, 484 and 495) not being widely distributed throughout the strata.

The maximum CTD profile depths ranged from < 50m to > 300m. Surface data were successfuly collected in all strata (Fig. 1 & 2). In 1998 the depths sampled were consistent with previous years.

Historical Context: Temporal Trends

The summer surveys have been conducted between 23 June (consecutive day 175) and 6 August (consecutive day 219; Fig. 2). The first survey samples the 4X area (median date: 9 July; range: 23 June to 31 July) and the second survey samples the 4VW area (median date: 22 July; range: 23 June to 6 August). Hence, the sampling dates are approximately 2 weeks earlier in the 4X area. The dates have been relatively consistent over the years. However, in a few strata (e.g. 440-450 and 470-78) the sampling dates during the first few years of the survey series (~1970-80) were 5-20 days later than in the more recent years.

With the exception of strata 470 to 472, the sampling dates in 1998 were generally typical of those in recent years. Sets in strata 470 to 472 were approximately 2 weeks later than the average sets in these strata.

Near Surface Temperatures

Means and 1998

The overall range of near surface temperatures within the survey domain and during the complete survey time period (1970-98), is approximately 6°C to 21°C (Fig. 3,8). The range of temperatures within a strata differs considerably between strata. In some strata, the range is only a few degrees whereas in others it is >10°C. The near surface temperatures in 1998 ranged from 8.13 to 19.0°C which was within the previously observed limits (Fig. 3,8). In 4VW, temperatures from many stations were above the 1970-97 75th percentiles. However, strata 451, 463, 465 and 466 recorded all

temperatures below the medians. In 4X, Bay of Fundy and Southwest Nova Scotia strata (482 thru 495) below average water temperatures were generally recorded. Historic lows was recorded for strata 480. However, for the remaining strata in 4X (470 thru 481) near surface temperatures were above the medians with many values above the 75th percentiles except for the shelf edge stratum 478 where temperature was at the 25th percentile.

The geographic distribution of the 1998 near surface temperatures (Fig. 4) are warmer than that of the long-term (1980-90) strata mean temperatures (Fig. 5) for all of 4W and the eastern 4X strata. Bay of Fundy and 4Vs are within long term means and 4Vn observed warmer surface waters. The lowest temperatures (8.13°C) occurred on Brown's Bank and along the inshore strata off southwest Nova Scotia and the Bay of Fundy (485, 490, 495). The highest temperatures occurred in strata 464 (19°C) and most of the other 4W strata. Near surface temperatures throughout the remainder of the survey domain were between 8° and 18°C.

These patterns are also evident in the distribution of 1998 strata mean temperatures (Fig. 6). The strata mean temperatures were near or above the 1970-90 means (Fig. 5). The cumulative frequency distributions of the temperatures (Fig. 7) indicates that the temperatures sampled in 1998 were higher in 4VW than in most previous years, although they were not the highest in the history of the survey series. However, the cumulative frequency for 4X overall fell within previous ranges.

Historical Context: Temporal Patterns

The time series of near surface temperature percentiles is shown in Fig. 8. In 4VW, the near surface temperatures were low from 1970-74, tended to increase from 1975 to 1978, decreased in 1980 and increased to a mean historical high for the survey series in 1984. Temperatures dropped in 1985 and 1986 with an increase in 1987. From 1987 to 1992, the temperatures trended downward towards a historical mean low for 1992. 1993 temperatures were the second highest recorded throughout the time series followed by a 3°C mean temperature drop in 1995. Since 1995 the temperatures have increased and for 1998 mean temperatures are about equal to the long term means.

The time series pattern described for 4VW seems to be smoother in 4X. Historical high near surface temperatures were recorded in 1984 and historical lows in 1981 and 1996. These historical lows do not match up with those of 4VW but 4VW do show parallel trends. In 4X the minimum and 25th percentile temperatures are generally lower than 4VW. The 25th percentile of the temperatures range between 8° and 15°C in 4X and between 11° and 17°C in 4VW.

These general patterns are also reflected in the time series of stratified mean temperatures (Fig. 9).

The strata specific time series of temperatures are shown in Fig. 10. The general pattern indicated on the time series plots (Fig. 8) are also shown by the individual strata. The general pattern for 4X as a whole is representative of the pattern in each of the 4X strata.

Near Surface Salinities

Means and 1998

The near surface salinities sampled within the survey domain have ranged from about 28 to 33.7 psu (Fig. 11, 13) during the 1970-98 time period of the surveys. As with temperature, the salinity range within strata differs between strata. The range in some strata is only a few tenths of a psu, whereas it is >4 psu in others. The near-surface salinities in 1998 ranged from 28.437 to 32.705 psu (Fig. 4,13,14) which falls well below previously observed limits (Fig. 11,12). The lowest 1998 mean salinities were in 4Vs with historical lows in strata 442 and 445. Sable Island Bank and Western Bank near surface salinities are near average but the remainder of 4W recorded salinity values well below average with record low salinities in strata 460 and 462. Strata 465 recorded the highest salinities whereas strata 470 thru 483 and 485 show near surface salinities <1 psu lower than average. The remainder of 4X and the Bay of Fundy records salinities at approximately .5 psu lower than average. The near surface waters off southwest Nova Scotia and the Bay of Fundy (strata 480 thru 495) tend to have the highest near surface salinities. In the eastern, central and south-western Scotian Shelf areas the relatively low and high salinities correspond with the relatively low and high temperatures. In the Bay of Fundy the higher salinities do not correspond with higher water temperatures. The correlation here might be better related to strong tidal conditions and mixing of the water column. This general pattern is also reflected in the contoured (Fig. 5) and strata mean salinities for 1998 (Fig. 12). The cumulative frequency distributions of the salinities (Fig. 13) indicates that the 1998 salinities were lower in 4VW than in most previous years, although they were not the lowest in the history of the survey series. In 4X, the salinities fell below all previous recorded values.

Historical Context: Temporal Patterns

Like temperatures, the near surface salinities have varied inter-annually. The trends in the distribution of salinities for 4VW and 4X show similar patterns (Fig. 14). In 4VW, the median salinities from 1970 to 1993 were generally around 31 psu. From 1995 to 1998, the salinities have been decreasing. Mean historical highs were recorded in 1990 and historical lows recorded in 1994. In 4X, the trends in median salinities are apparent. Historical high salinities were recorded in 1976 but very stable salinity conditions (median approximately 31.3 psu) were maintained from 1970 thru 1990. Salinities have been decreasing since 1990 and are at historical lows for 1998.

The stratified mean salinities for 4W and 4Vs show trends similar to that of the above and correspond with that of the temperatures (Fig.9). The salinities increased during the 1970's thru to 1990 in 4Vs and declined since 1990. In 4W and 4X Scotian Shelf salinities were stable from 1970 thru 1990. Since 1990 salinities have been dropping. Bay of Fundy salinities have risen in the 1970's, declined through the early 1980's and increased during the late 1980's. As in the other areas, salinities have been in decline during the 1990's.

The strata specific time series of individual station salinities are shown in Figure 15. There seems to be a general lack of trend for some strata but the historical context described above can be seen in strata 441,457,459 thru 462 and most of 4X.

DISCUSSION

The oceanographic climate has been consistently monitored within the Scotia-Fundy region at only one offshore station. This is the Prince 5 station located in 90-100 m of water on the northern side of the tidally energetic mouth of the Bay of Fundy. Full hydrographic profiles have been recorded at this station once a month since 1924 (Trites and Drinkwater 1983). A second indicator of offshore conditions has been constructed from hydrographic profiles taken within Emerald Basin on an opportunistic basis (Petrie et al. 1991). Both of these time series contain a decadal time period trend in temperature that is horizontally and vertically coherent throughout the Scotia-Fundy region (Petrie et al. 1991). The trend indicates that the late 1930's to early 1940's, and the early 1960's, were relatively cold, whereas the late 1940's to early 1950's, and the 1970's and 1980's were relatively warm. The trend during the later 1980's has been toward decreasing temperatures such that the early 1990's are below the long-term mean. The research vessel surveys have been conducted within this framework of climate change.

The Canadian bottom-trawl research vessel summer survey program began in 1970. Because of the stratified random allocation of set locations, the potential exists for the patterns and trends in temperatures and salinities observed during the surveys to be confounded by variation in the location and timing of the sampling. Hence, the trends in temperatures and salinities observed during the surveys are only indicators of trends in the hydrographic conditions that were sampled and are not always good indicators of actual changes in the hydrographic climate. Fortunately, this is not as large a problem for the summer surveys as it is for the spring surveys. This is discussed more fully in Page et al. (1994).

Whether the changes are climatic in nature or not does not alter the fact that the changes are indicative of inter-annual differences in the type of hydrographic habitat sampled. As such, they may be related to inter-annual variations in estimates of fish distribution and abundance. This possibility has been suggested by several authors including Pinhorn and Halliday (1985). Page et al. (1994) and Smith et al. (1994) have

examined the associations between cod and haddock abundance and sampling depth, water temperature and salinity. Smith, Perry and Fanning (1991) have shown that during the 1979 to 1988 period inter-annual changes in the proportion of 4VW bottom waters identified as Cold Intermediate Layer (CIL) water coincide with changes in the estimated abundance of 4VsW cod. When the proportion of the CIL is large (small), and hence the temperatures are relatively cool (warm), the estimate of cod abundance is relatively low (high). The suggested trends in temperatures may, therefore, be associated with changes in the distribution and abundance of cod within at least the 4VW area. This connection has been explored more fully by Smith and Page (1996). The connection with haddock has been explored by Smith and Page (1994). The possibility of a relationship between temperature and herring was explored by Stephenson et al. 1995.

Acknowledgements

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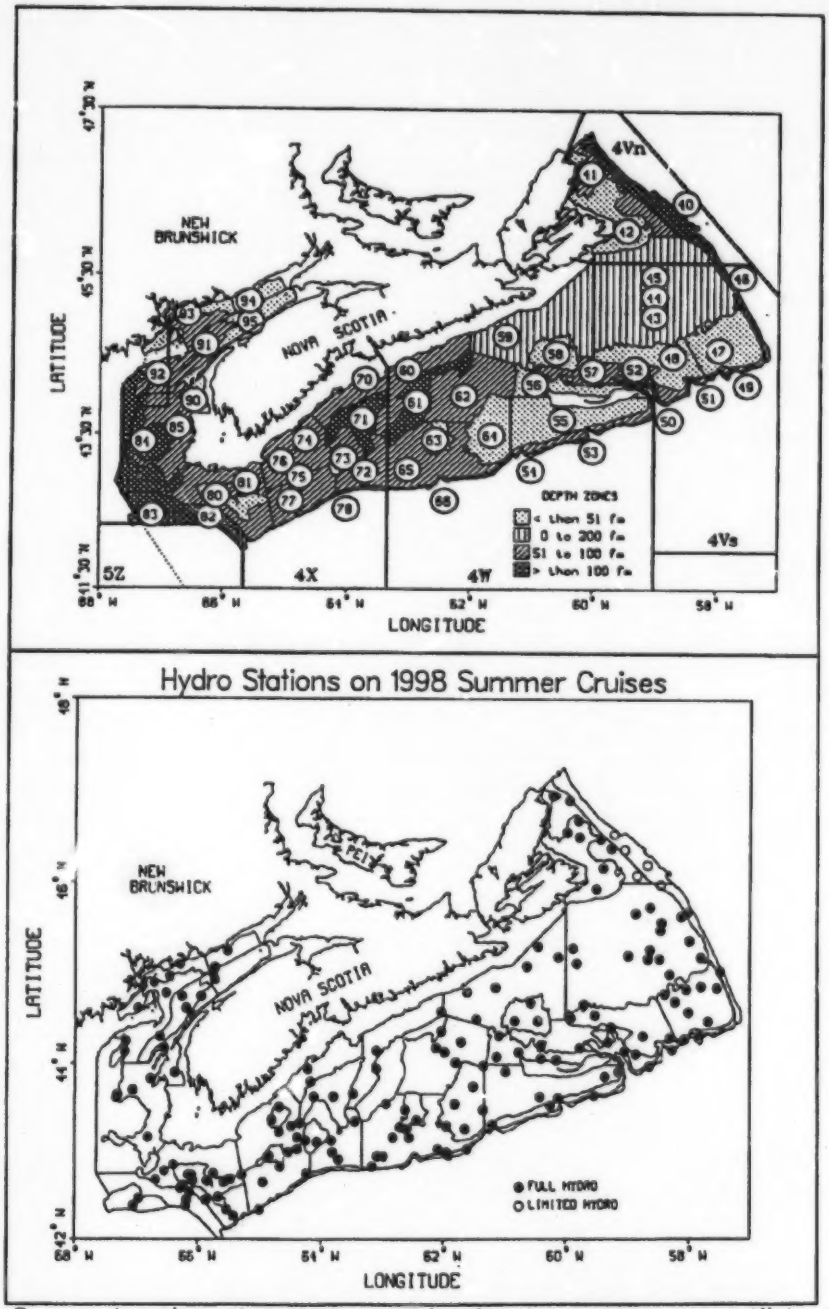


Figure 1: Survey domain and strata boundaries for the summer groundfish research vessel surveys conducted within NAFO area 4VWX from 1970–1998 (top panel) and the location of hydrographic sampling stations taken during the 1998 survey (bottom panel). In the bottom panel solid circles indicate a CTD cast and open circles indicate where only bottom temperatures and salinities were measured. In the top panel the numbers enclosed within circles are the strata designations. Only the last two digits of the summer strata designations are shown.

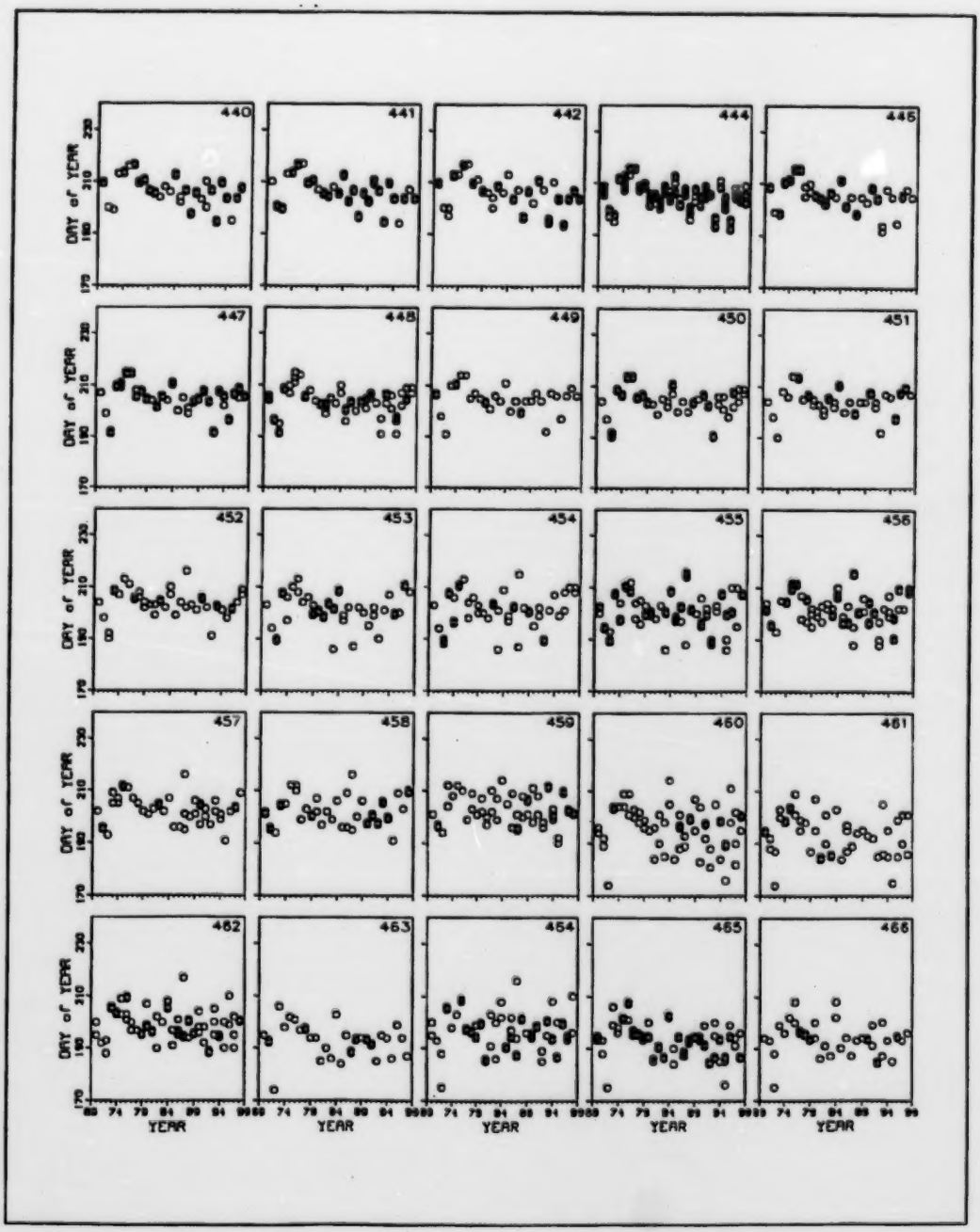
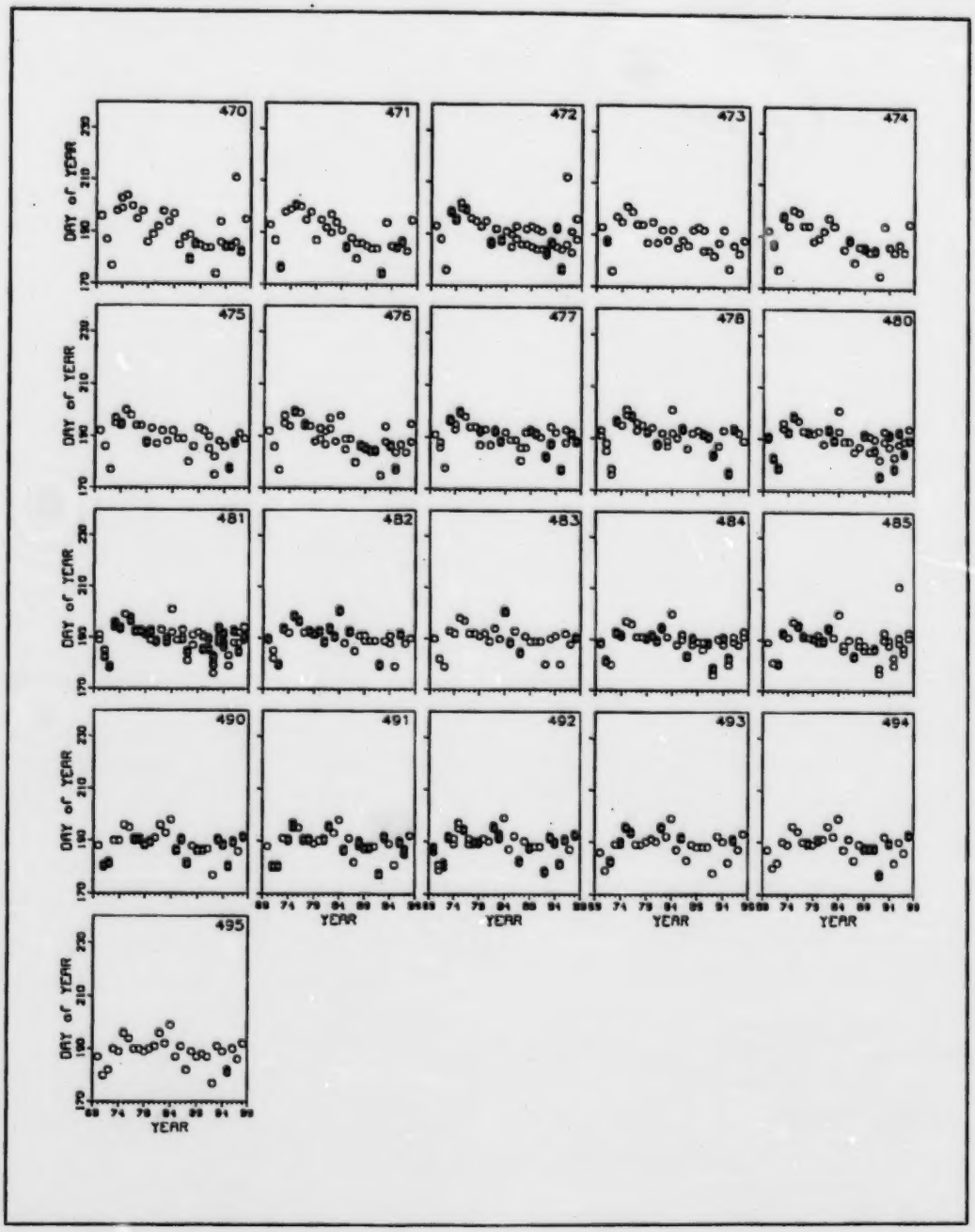


Figure 2: Time series of the consecutive day of sampling within the summer 4VWX surveys. The numbers in the upper right hand corner of each panel indicate the survey stratum. Each open circle represents the sampling day of one hydrographic station.



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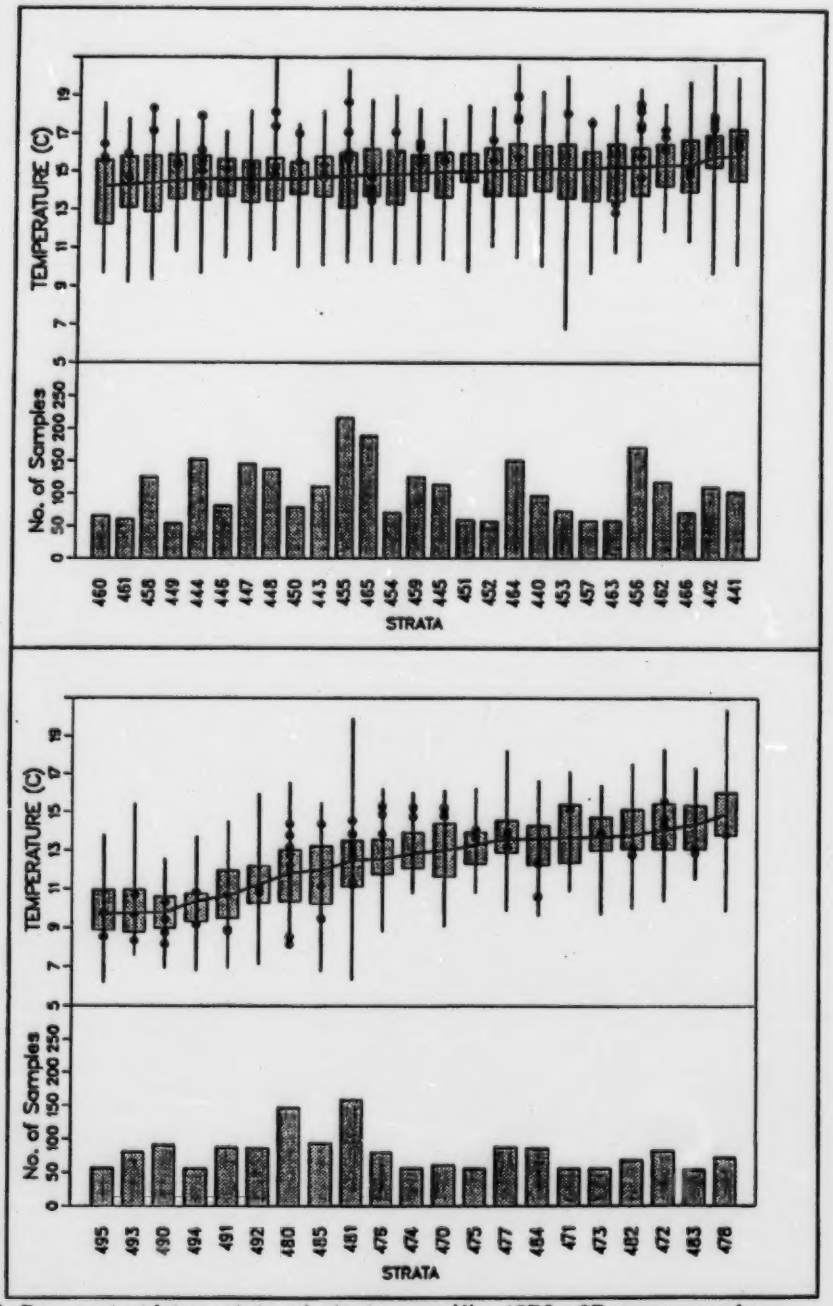

Figure 3: Box and whisker plots of strata specific, 1970–97, near–surface water temperatures for strata within 4VW (top panel) and 4X (lower panel), ordered by temperature medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–97 period. Solid circles are 1998 observed temperature data.

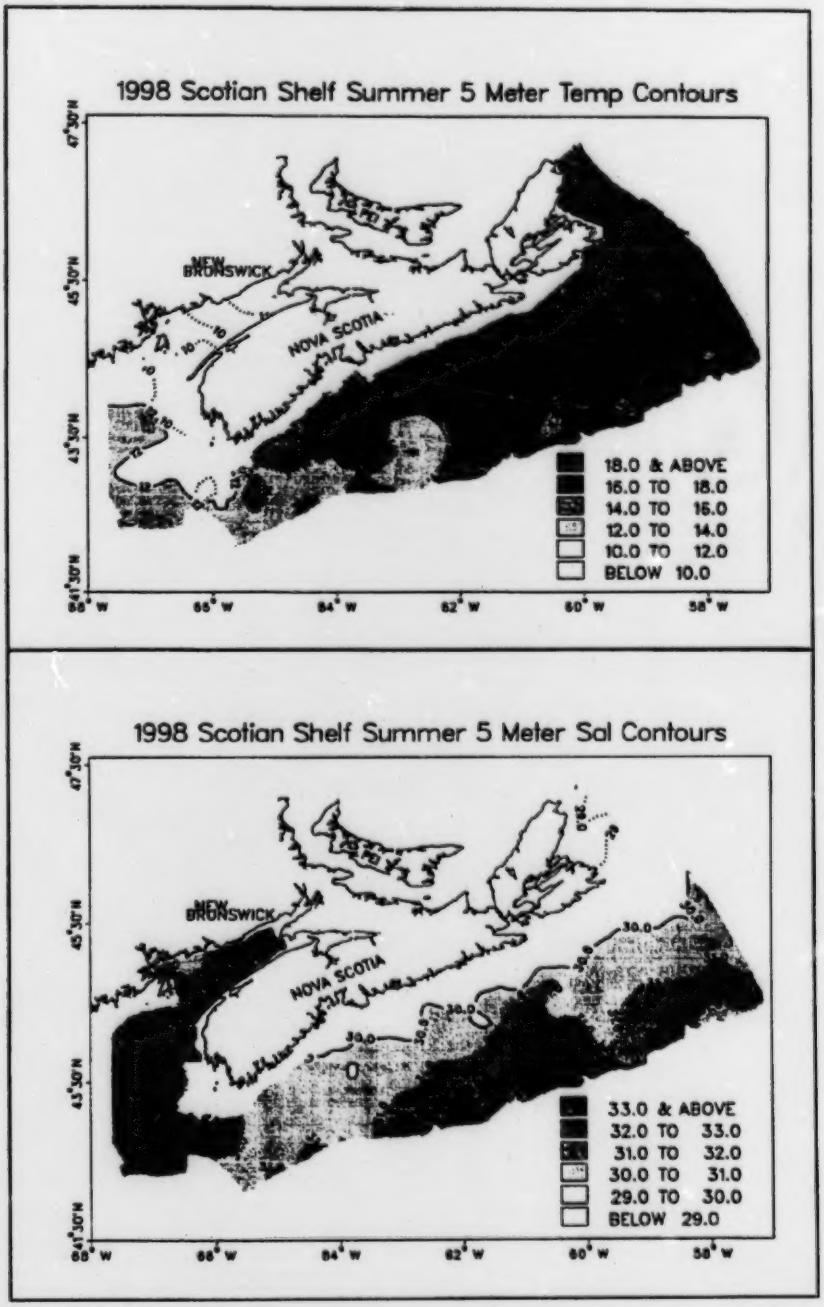

Figure 4: Contour maps of 5 meter temperature and salinities within the 4VWX Canadian research vessel bottom-trawl surveys conducted during the summer of 1998.

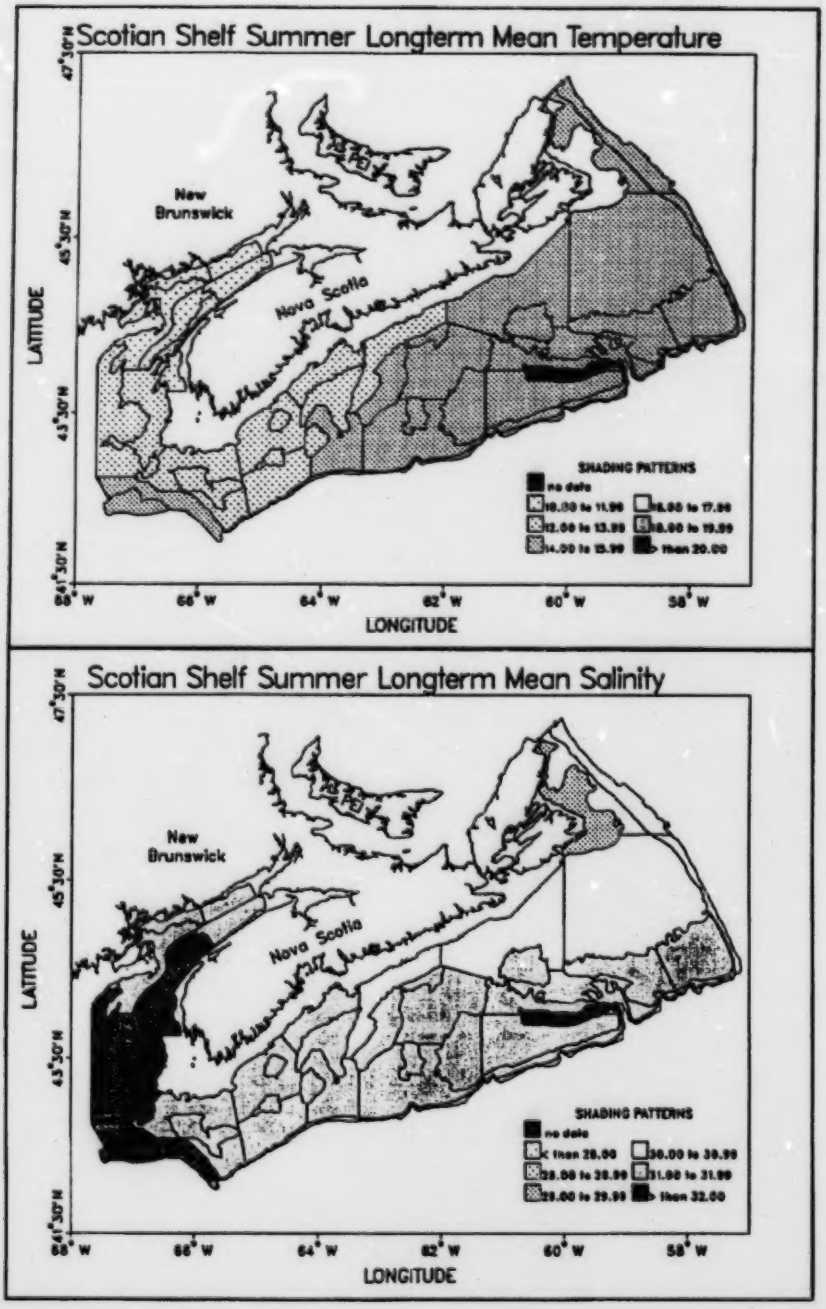

Figure 5: Map of 5 meter strata long term mean temperatures (top panel) and salinities (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom-trawl survey conducted during the summer of 1980-1990.

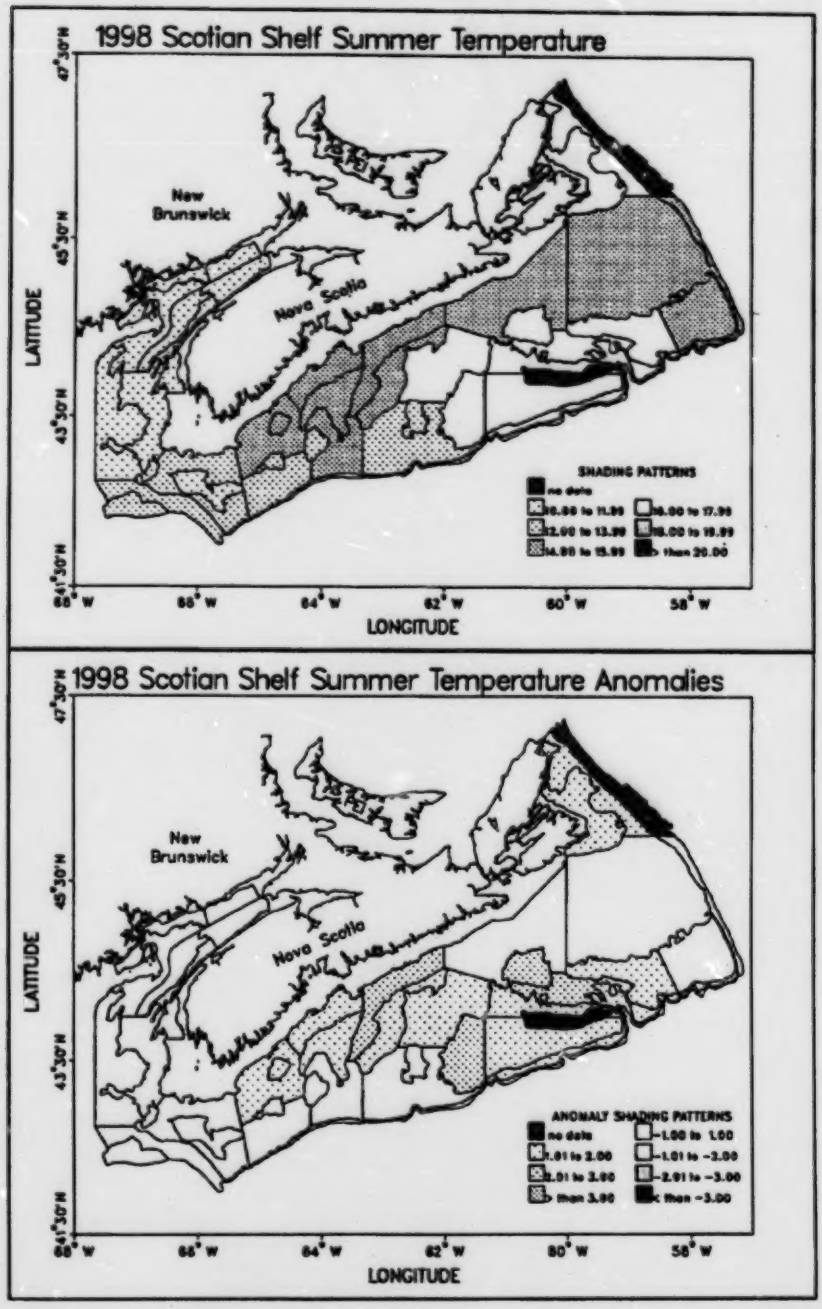

Figure 6: Map of 5 meter strata mean temperatures (top panel) and temperature anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom–trawl survey conducted during the summer of 1998.

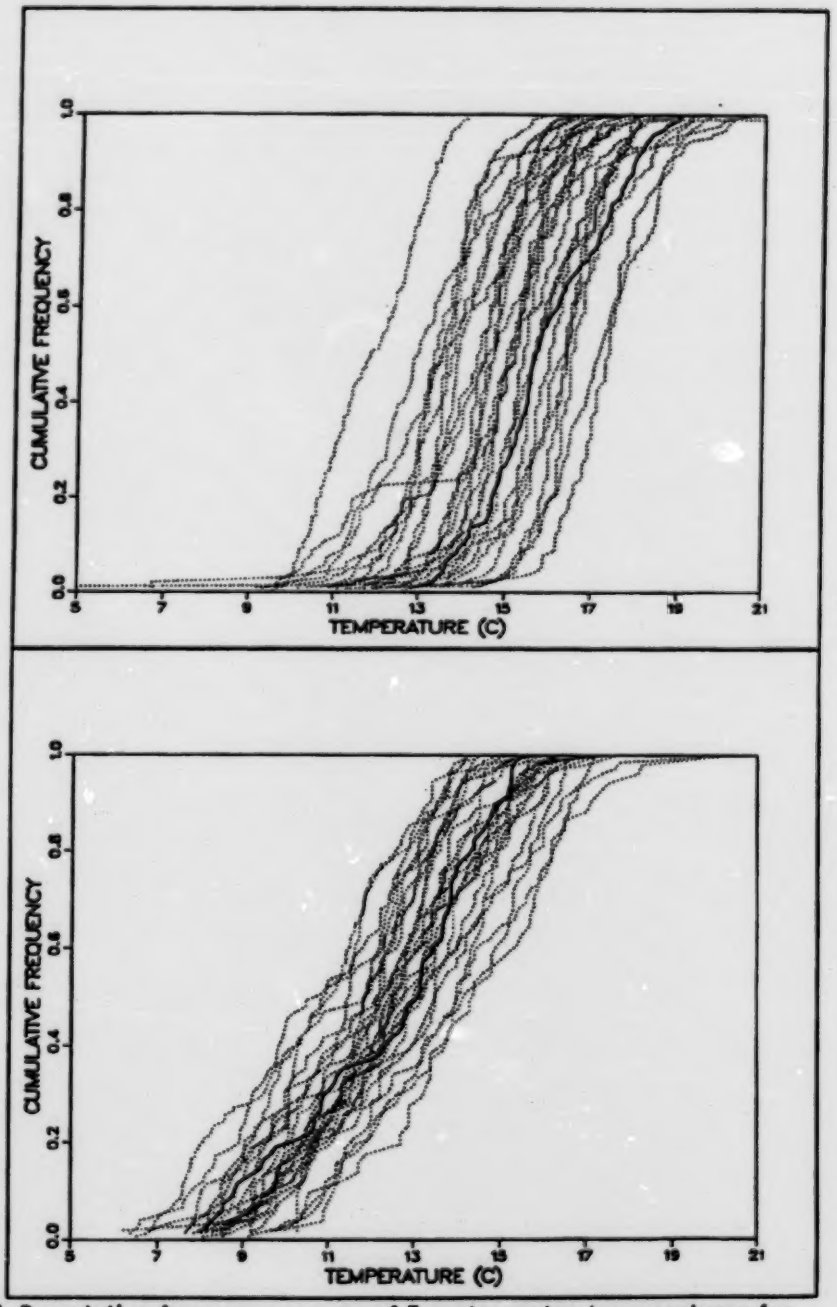

Figure 7: Cumulative frequency curves of 5 meter water temperatures for the 1970–98 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–97 and the heavy solid line is for 1998.

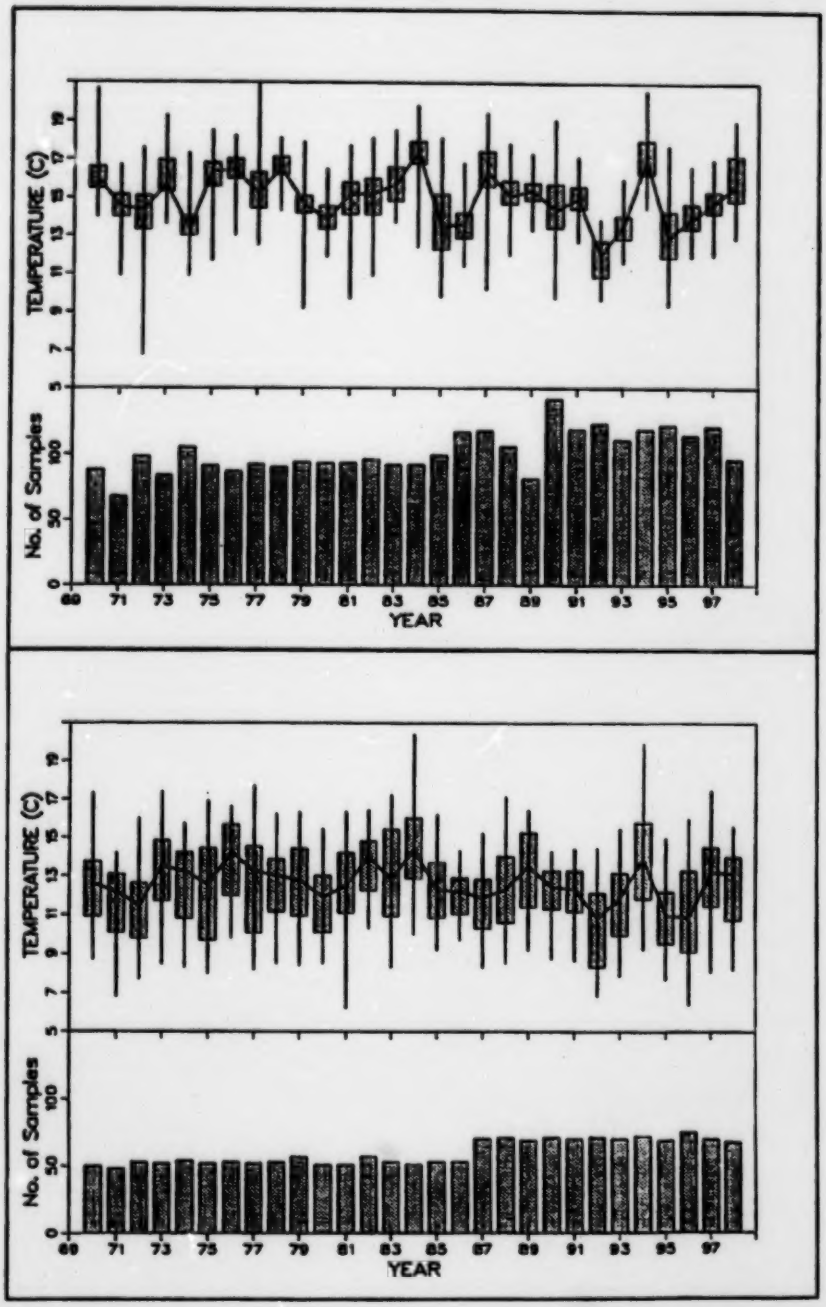

Figure 8: Box and whisker time series plots of near-surface water temperatures for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970-98 period.

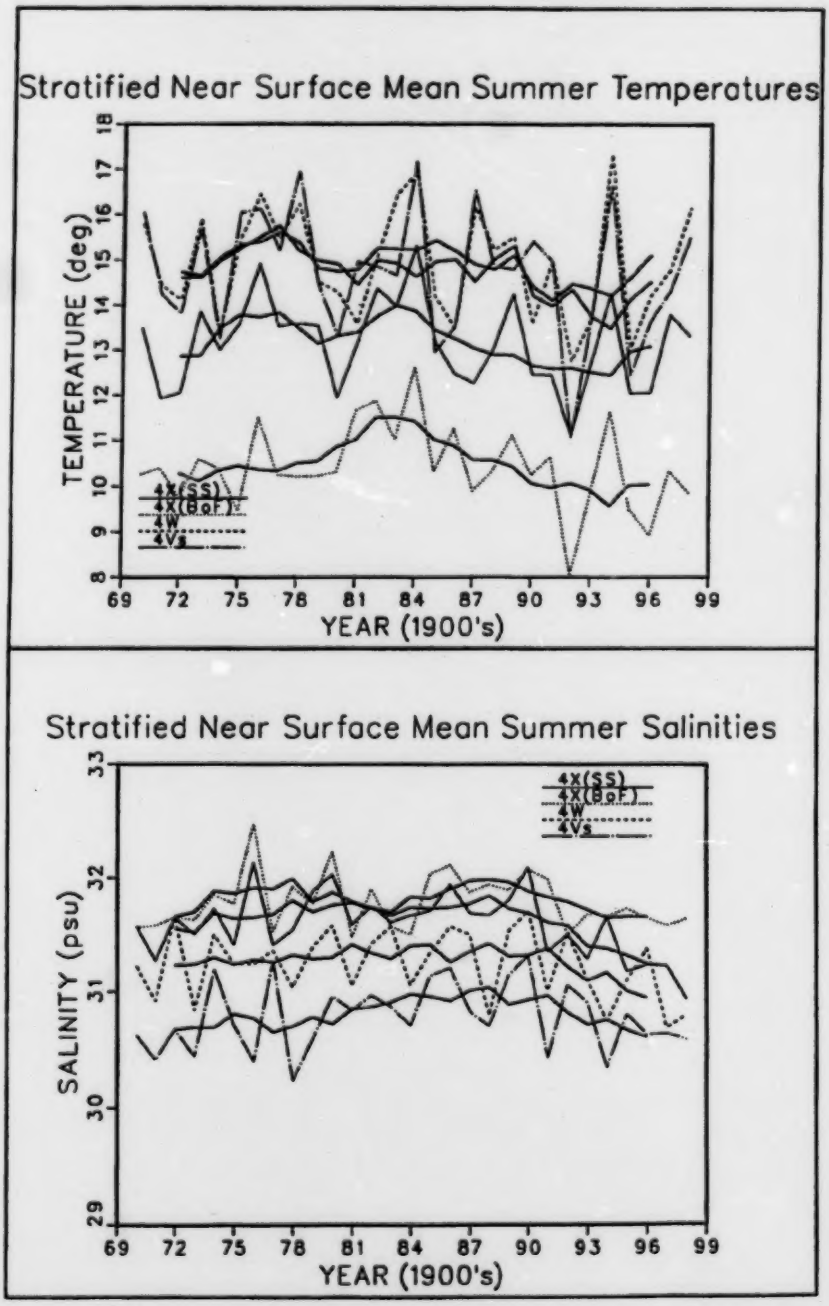

Figure 9: Time series of stratified mean 5 meter temperatures(upper panel) and salinities (lower panel)for Canadian summer research vessel groundfish surveys. The smooth curves running through each series is a five year running mean.

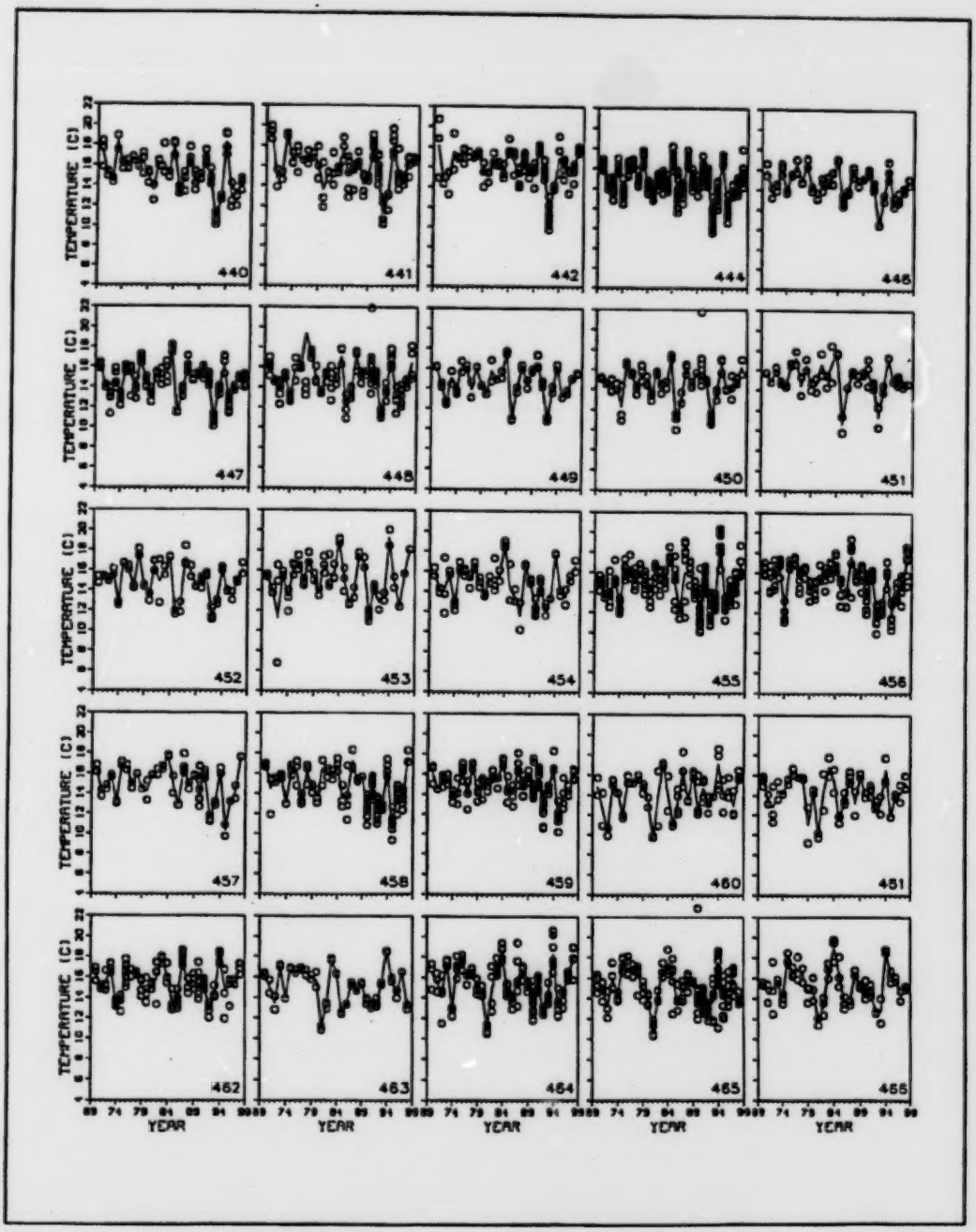

Figure 10: Time series of 5 meter temperatures within the summer 4VWX surveys. The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the temperature at one hydrographic station.

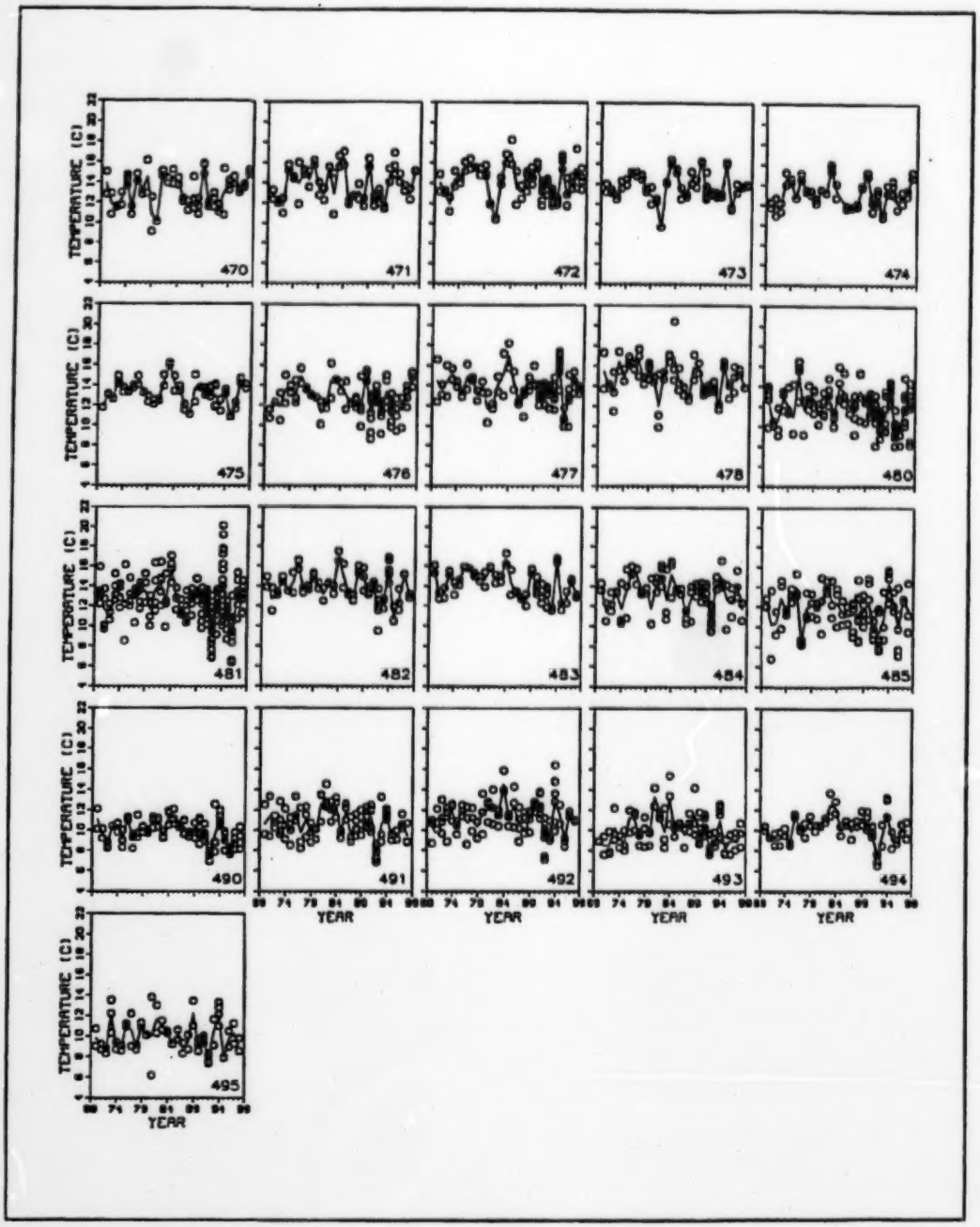

Figure 10 : continued

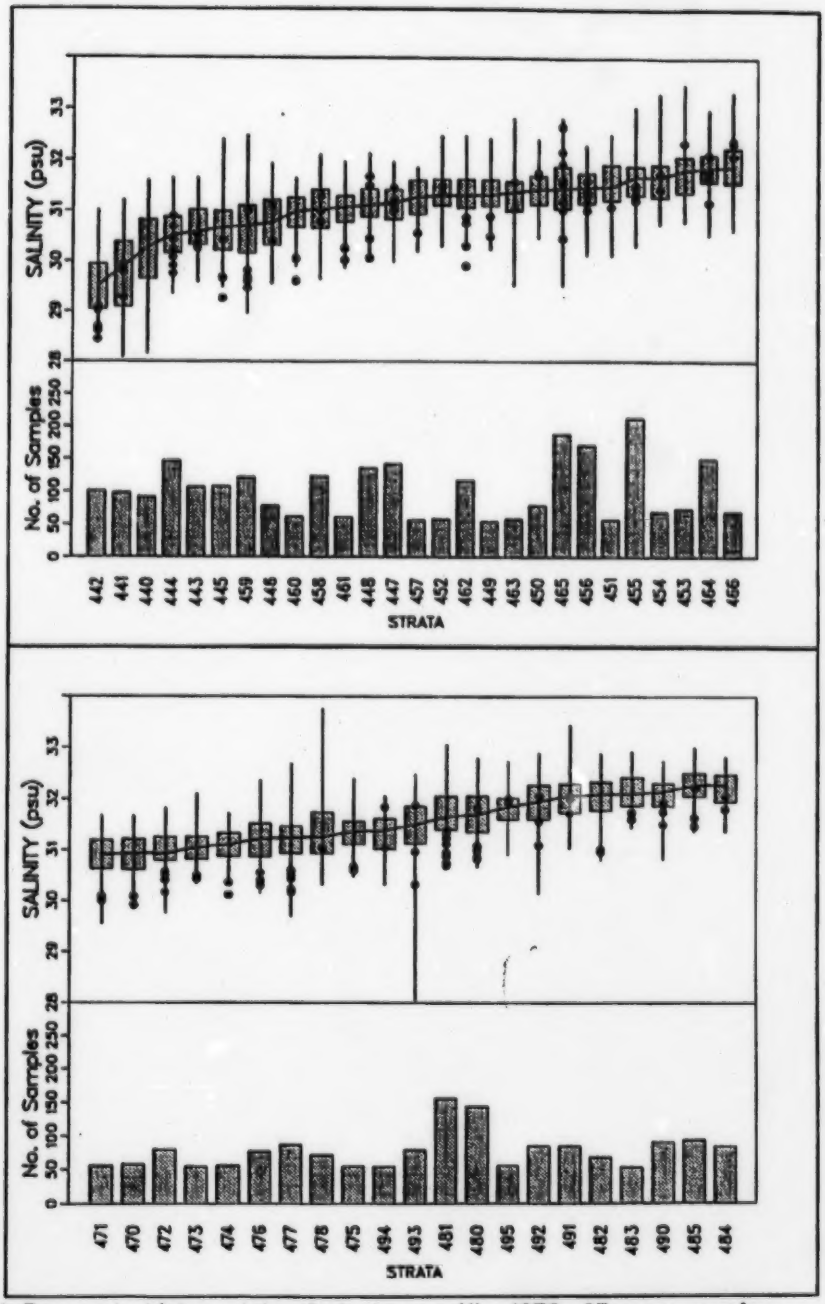

Figure 11: Box and whisker plots of strata specific, 1970–97, near–surface water salinities for strata within 4VW (top panel) and 4X (lower panel) ordered by salinity medians. The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each strata over the entire 1970–97 period. Solid circles are 1998 observed salinity data.

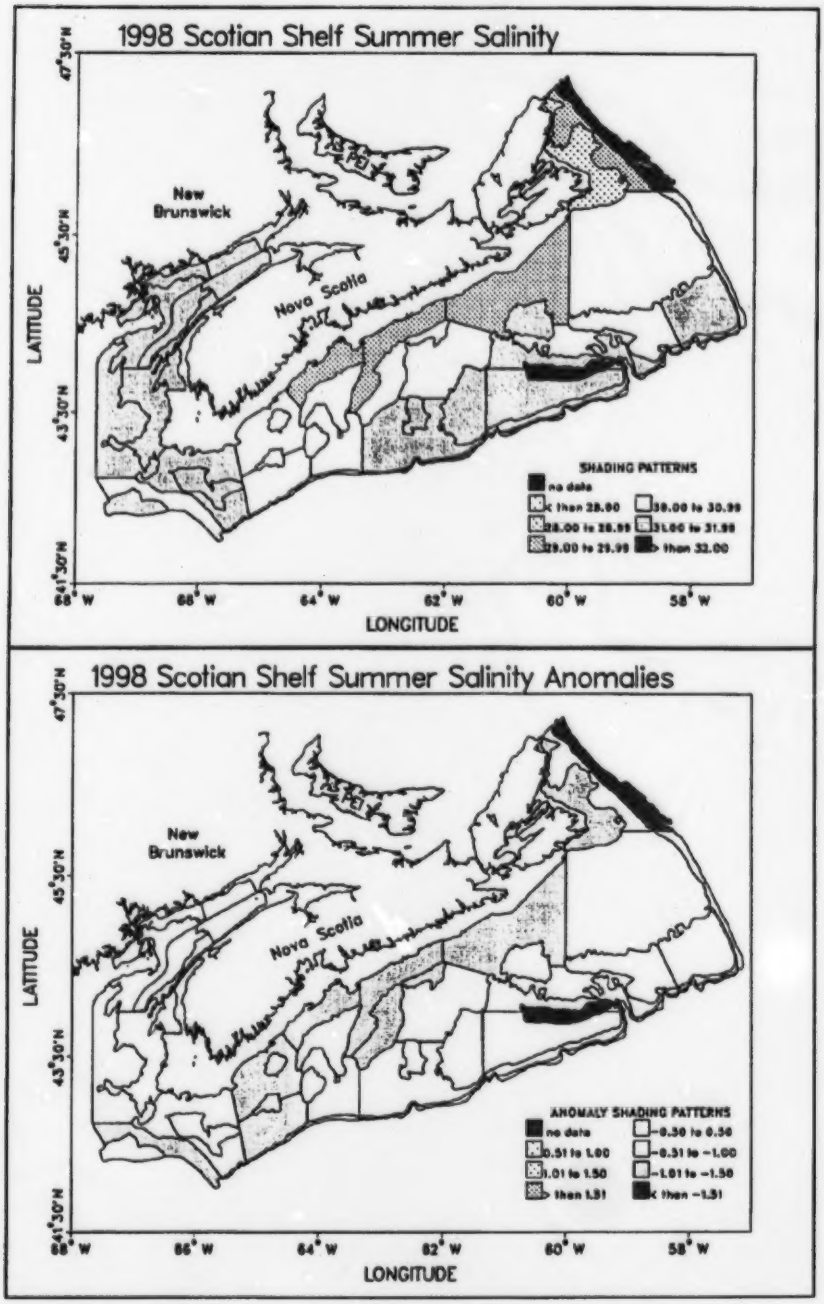

Figure 12: Map of 5 meter strata mean salinities (top panel) and salinity anomalies (bottom panel) within NAFO statistical area 4VWX during the Canadian research vessel bottom–trawl survey conducted during the summer of 1998.

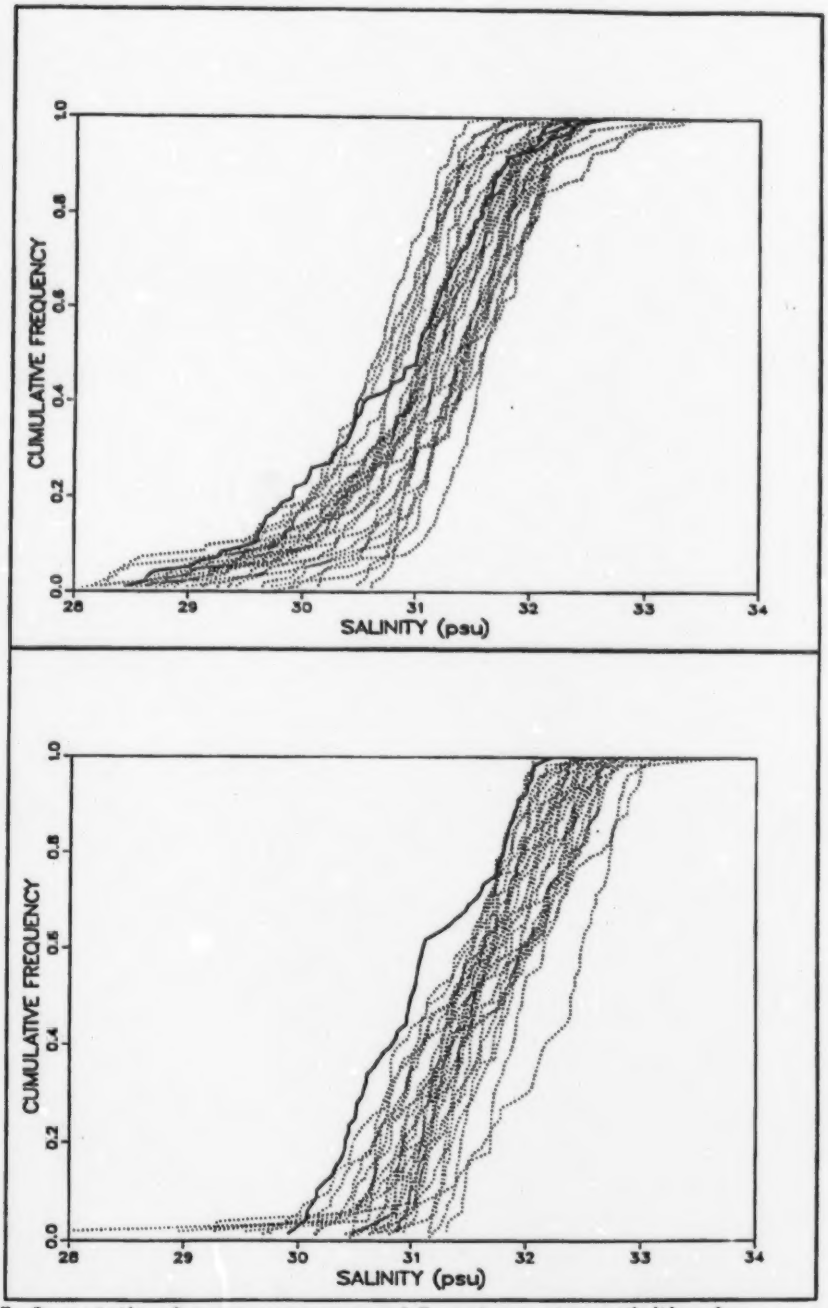

Figure 13: Cumulative frequency curves of 5 meter water salinities for the 1970–98 Canadian research vessel bottom–trawl summer 4VW (top panel) and 4X (lower panel) surveys. Each line represents the cumulative frequency for a single year. The dotted lines are for the years 1970–97 and the heavy solid line is for 1998.

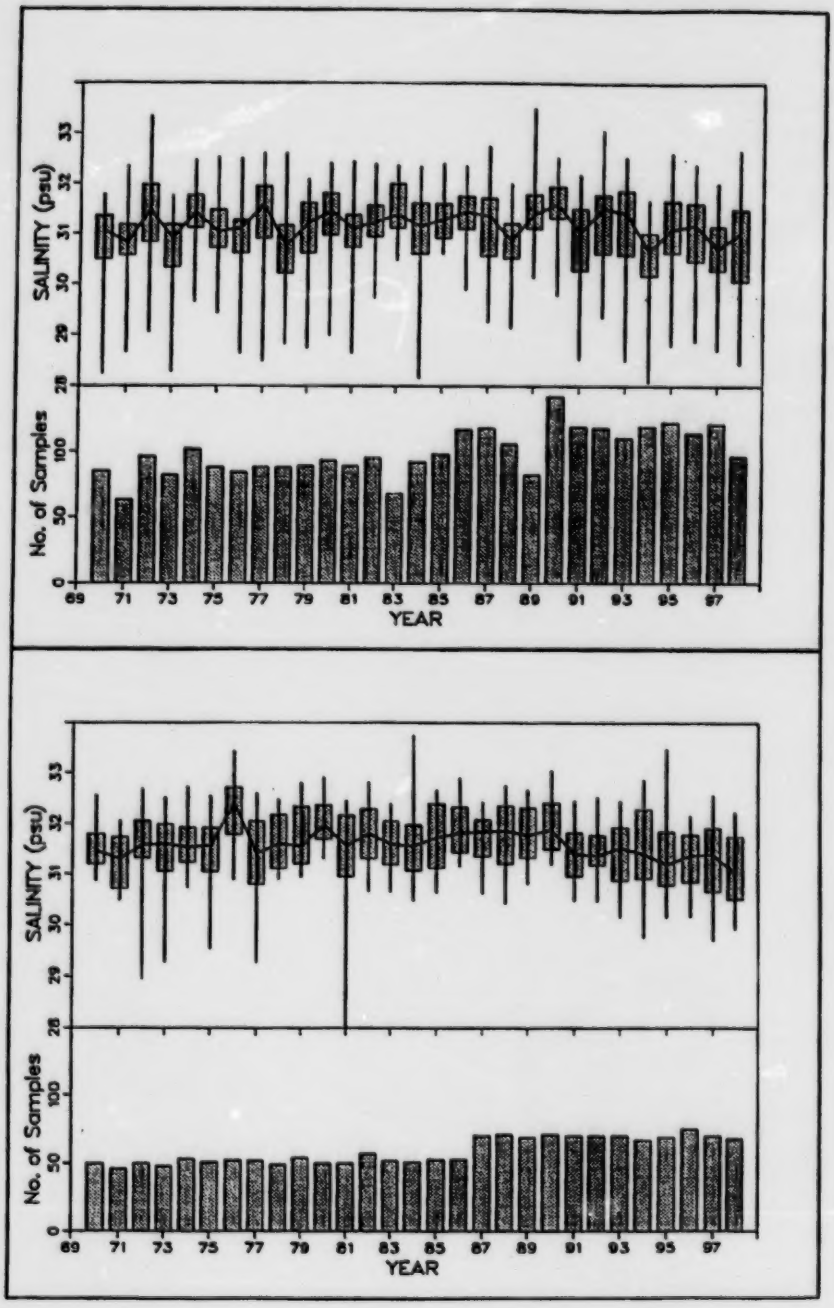

Figure 14: Box and whisker time series plots of near-surface water salinities for each year within 4VW (top panel) and 4X (lower panel). The maxima, 75th percentiles, medians, 25th percentiles and minima are shown along with the total number of samples taken within each year over the entire 1970-98 period.

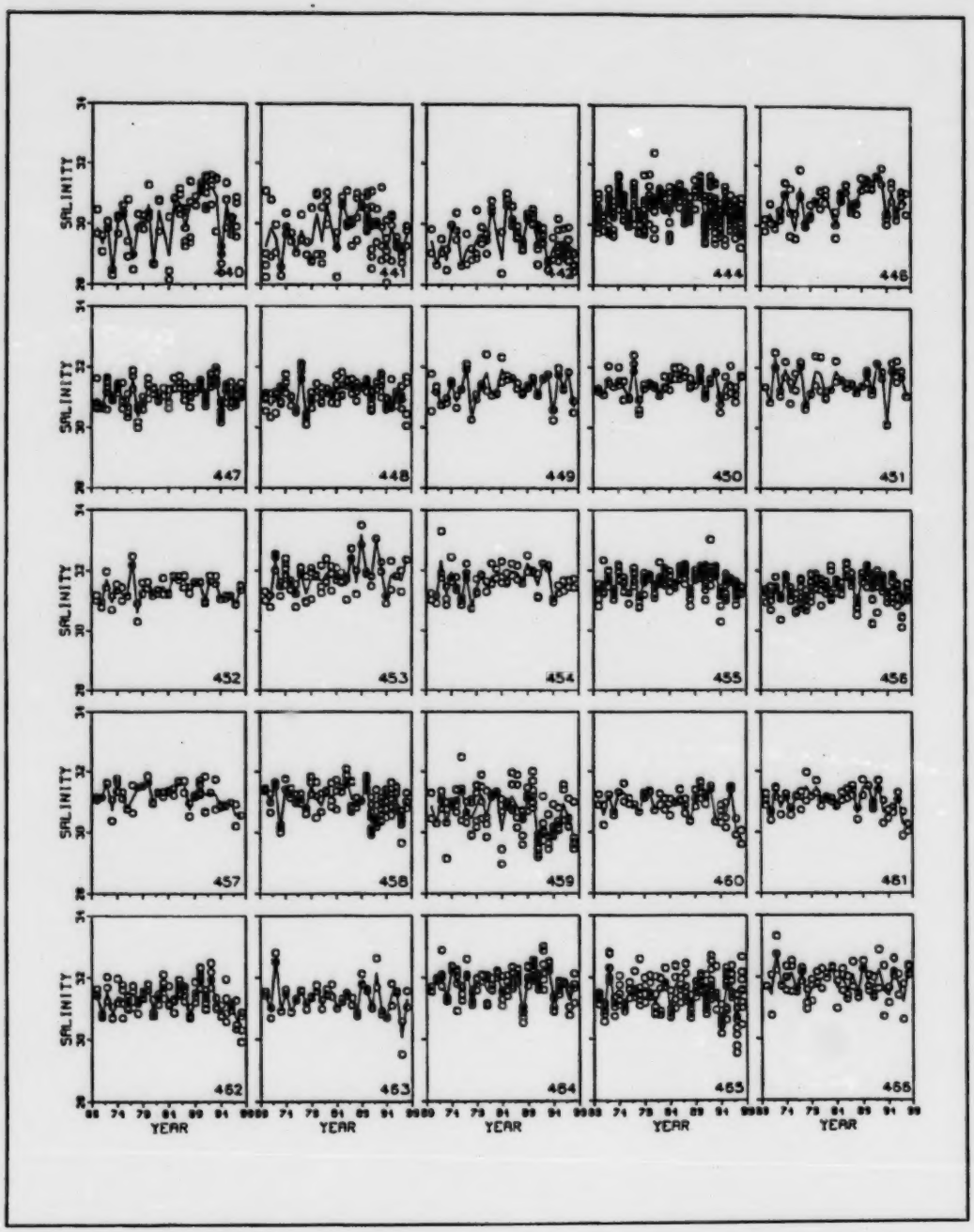

Figure 15: Time series of 5 meter salinities within the summer 4VWX surveys.
The numbers and letters in the lower right hand corner of each panel indicate the survey stratum. Each open circle represents the salinity at one hydrographic station.

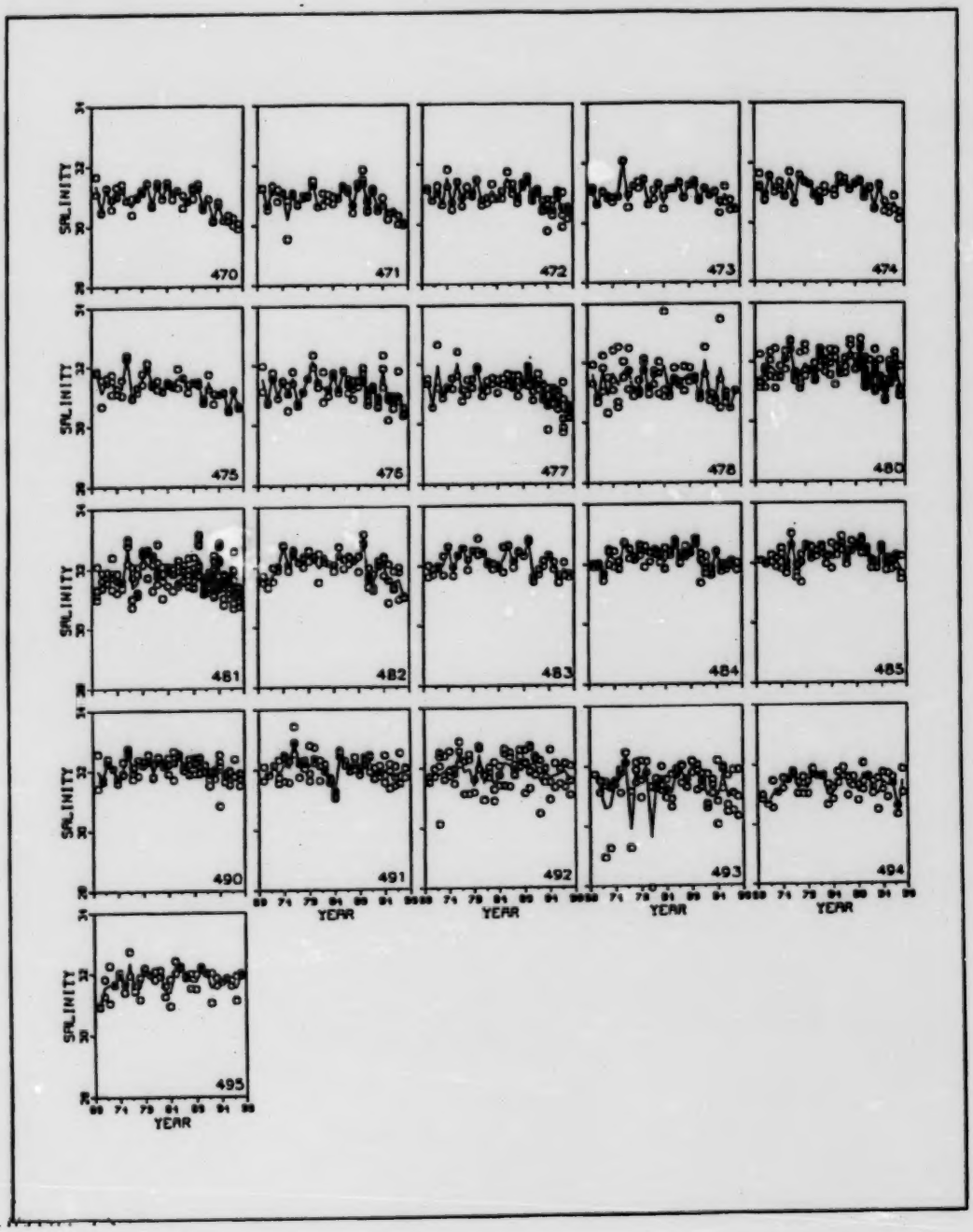

Figure 15 : continued